Insulation System for Ultra-High Temperature Applications

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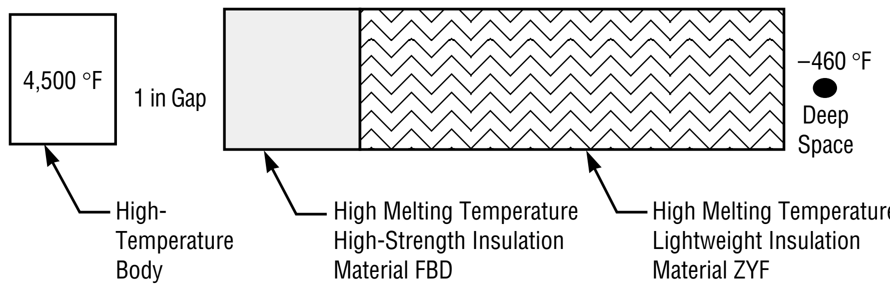

Figure 67.—Conventional thermal protection system.

This investigation evaluated a new material system for concentrated solar energy applications. There are a few commercially available materials that could act as a thermal barrier at 4,500 °F for a short period of time. However the materials by themselves may not be suitable for the long-duration required by a storage-type solar energy engine. This study introduces a new concept of a material system to improve performance under these harsh conditions. This concept could be developed with a small budget, and experimentally proven for a high-temperature application.

In this study, thermal analysis was used to compare a conventional approach to the new concept. While insulating an engine operating at 4,500 °F, the new concept reduced the outside surface temperature 1,600 °F below the conventional approach over the same time period.

Conventional thermal protection system: zirconia-type FBD and type ZYF materials both have high-melting temperatures of 4,700 °F as used for this study. The zirconia FBD is used as inside insulation facing the absorber wall. The gap between the FBD and absorber wall is 1 in. Geometry models were generated consisting of the absorber and 1-in-thick layer of FBD surrounded by 4 in of ZYF felt insulation. It was assumed that the absorber temperature is 4,500 °F. With the intention to correlate the analytical results with ground test data without the effects of deep space radiation, the outside surface was considered adiabatic for the comparison of the insulation methods. The transient temperature distribution across the insulation walls is shown in figure 68. The temperature of the outside wall of the ZYF insulation was found to be 1,907 °F after the 4,500 °F was impressed at the absorber for 7,200 sec.

The proposed high temperature radiation shield system consists of high-strength and low thermal conductivity material overlaid with low emissivity and high melting temperature metal coatings on both surfaces as shown in figure 69. The core material could have physical and thermal properties similar to the ZIRCA type FBD. The overlaid surfaces could be made of a metal having physical and thermal optical properties that are similar to tungsten. Thickness of the metal surface could be made sufficient to serve as a part of the support structure. The high-temperature, high-strength and high-thermal-resistant material layers are located to insulate a hot body (i.e., an solar energy engine absorber). The clearance between the first FBD layer and absorber wall is 1 in. The gaps between five FBD layers and the 4 in of ZYF felt

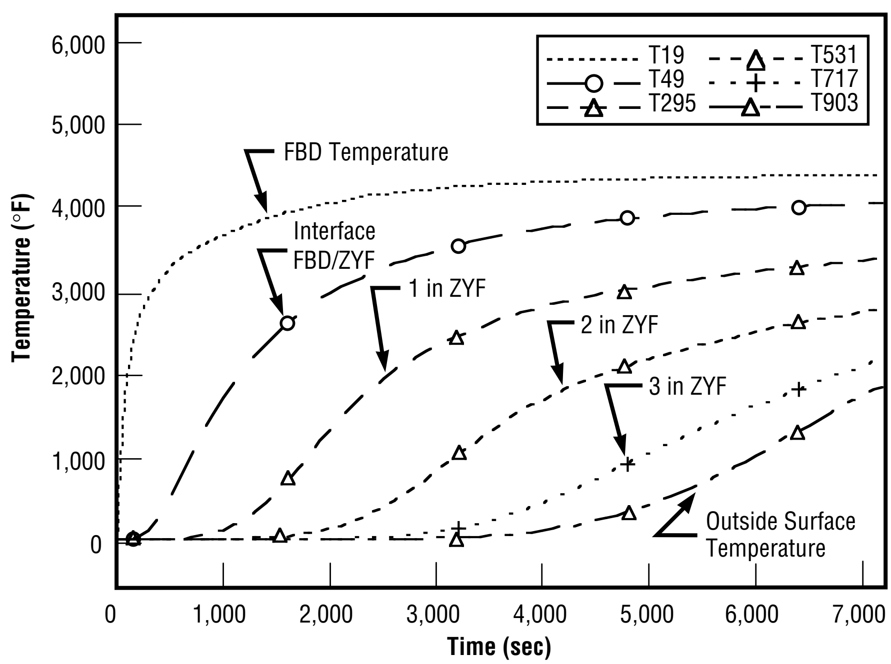

Figure 68.—Transient temperatures (°F) across insulation walls with 4-in ZYF (conventional TPS).

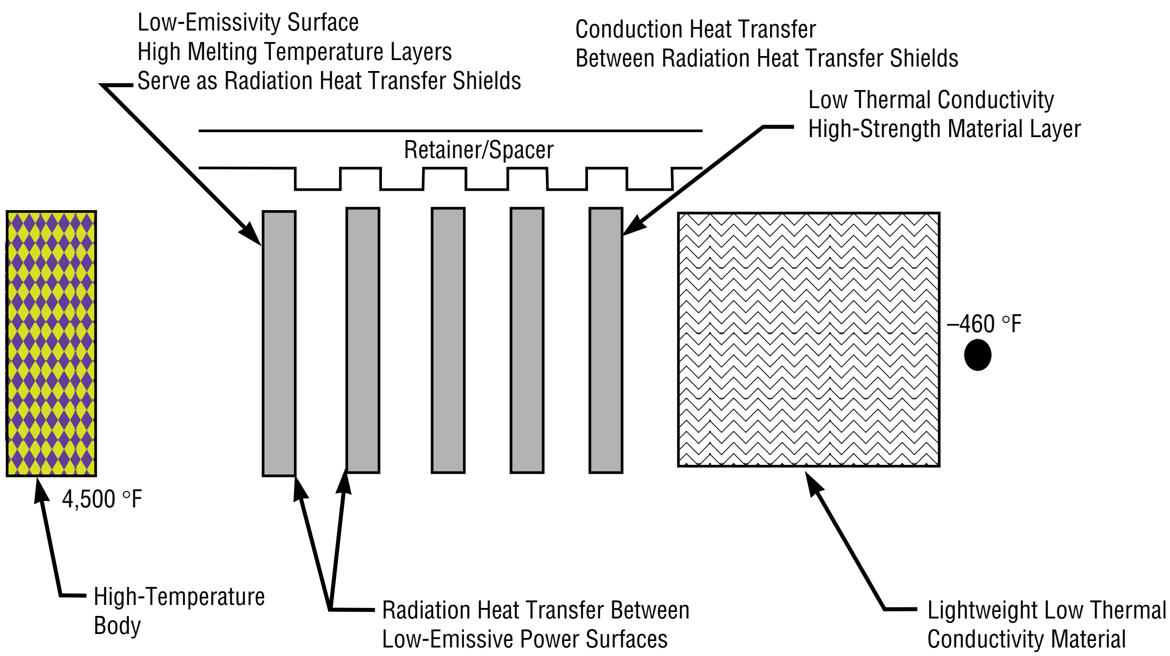

FIGURE 69.—Concept for a high-temperature radiation shield.

insulation are 0.3 in. It was assumed that the absorber temperature is 4,500 °F. With the intention to correlate the analytical results with ground test data without the effects of deep space radiation, the outside surface was considered adiabatic for the comparison of the insulation methods. The transient temperature distribution across the insulation walls is shown in figure 70. The temperature of the outside wall of the ZYF insulation was found to be 268 °F after the 4,500 °F was impressed at the absorber for 7,200 sec. The conventional TPS surface reached 1,907 °F under the same conditions. The same total thickness of insulation was used in both models to show the benefit of the radiation shield configuration. A new concept for combining radiation shields and high-temperature insulators shows promise for use in the extreme environments required for solar thermal propulsion. When the 1-in thickness of the insulation type FBD was divided into five 0.2-in-thick layers and coated with low-emissivity material, the temperature of the outside surface was reduced considerably (1,600 °F) from the conventional applica-

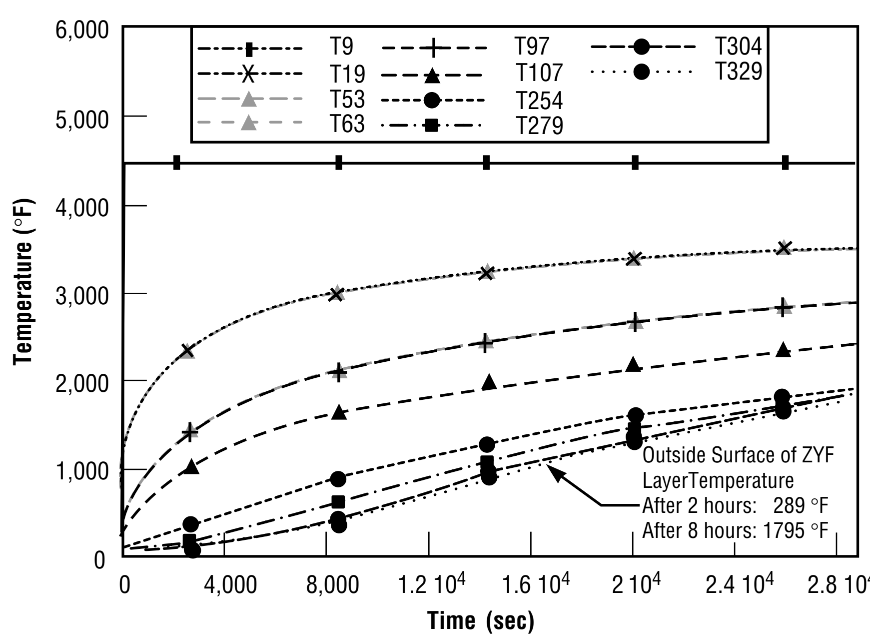

FIGURE 70.—Transient response of the high-temperature radiation shield system.

tion of these insulation materials over the same time period. Verification of these analytical results by testing is highly recommended.

This approach may improve performance for such high-temperature applications as the concentrated solar energy absorber/heat exchanger for the beyond LEO advanced space transportation (BLAST) engines. The new concept holds even greater potential for use in interplanetary travel vehicles. The insulation system concept should provide spacecraft a wider range of trajectories, mission profiles, and scientific objectives. Further potential industry applications include concentrated solar furnaces for material processing and synthesis, and high solar concentration devices for advanced medical research specially for the environment of the Space Station and the Moon surface.

Sponsor: MSFC's Preliminary Design Office

Biographical Sketch: Dalton Nguyen has a B.S. in mechanical engineering and works as a thermal engineer in the Structure and Dynamics Laboratory where he has been a member of the Engine and Propulsion Systems Team of the Thermal and Life Support Division since 1987. His contributions are in support of the Shuttle elements, Reusable Launch Vehicle programs including X–34 and X–33, new technologies such as the vacuum plasma spay processing, DC–XA liquid propulsion systems, and concentrated solar thermal energy propulsion programs.